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NASA TECHNICAL MEMORANDUM NASA TM-75644

EXPERIMENTAL STUDY OF THE VIDICON SYSTEM FOR INFORMATION RECORDING USING THE WIDE-GAP SPARK CHAMBER OF GAMMA - TELESCOPE "GAMMA-I."

(NASA-TM-75644) EXPERIMENTAL STUDY OF THE VIDICON SYSTEM FOR INFORMATION RECORDING USING THE WIDE-GAP SPARK CHAMBER OF GAMMA - TELESCOPE GAMMA-I (National Aeronautics and Space Administration) 19 p HC A02/MF A01 N80-10478 Unclas G3/35 45975

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Translation of "Experimentielnve Isledovanie systemiy semv infornuatsi v shirokozozornich iskrovich kamer Jomno teleschopo "Gamma I", Experimental Research of the vidicon system for information observation of the wide-gap spark chamber of gamma telescope"Gamma-I", Moscow, 1978

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 SEPTEMBER,1979

STANDARD TITLE PAGE

1. Report No. NASA TM-75644	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EXPERIMENTAL STUDY OF THE VIDICON SYSTEM FOR INFORMATION RECORDING USING THE WIDE-GAP SPARK CHAMBER		5. Report Date Sept. 1979
		6. Performing Organization Code
7. Author(s) V. V. Akimov et al.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address .SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASW-3198
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: "Eksperimental'noye issledovaniye vidikonnoy sistemy dlya s'yema informatsii s shirokozazornykh iskrovykh kamer gamma-teleskopa 'Gamma-I,'" Academy of Sciences, USSR, Institute of Space Research, Moscow, Report Pr-436, 1978, pp. 1-22.

16. Abstract

Several institutes in the USSR and France are involved in the development of the gamma-telescope "Gamma-I." One of the most important systems of the telescope are the wide-gap spark chambers which are used both to identify the gamma-quanta and also to determine the directions of their arrival. The construction of the gamma-telescope allowed two systems to be used for information recording with the spark chambers: photographic and vidicon system. The methods and the test results of the experimental research of the vidicon system characteristics, developed at the Center for Nuclear Research in Saclay, are described. It is shown that the basic parameters of the vidicon system are not worse than the basic parameter of the photographic system.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified	19	

ANNOTATION

Several institutes in the USSR and France are involved in the development of the gamma - telescope "Gamma - I." One of the most important systems of the telescope are the wide-gap spark chambers which are used both to identify the gamma-quanta and also to determine the directions of their arrival. The construction of the gamma - telescope allowed two systems to be used for information recording with the spark chambers: photographic and vidicon system. The methods and the test results of the experimental research of the vidicon system characteristics, developed at the Centre for Nuclear Research in Saclay, are described. It is shown that the basic parameters of the vidicon system are not worse than the basic parameter of the photographic system.

I. Introduction

After having successfully performed experiments SAS - 2 [I] and COS - B[2] the era of the high energy experimental gamma - astronomy /3*
has begun [Ef >50 MeV].

Further progress in this research area is related to the sensitivity increase of gamma - telescopes and this is achieved by the increase of the detector surface area and their angular resolution.

The USSR and French specialists have developed a light and powerful gamma - telescope "Gamma - I" [3]. The wide-gap spark chambers are used as a device to determine the particle arrival. In order to determine the angular resolution, the calibration, using the beam of the "marked" gamma - quantum of the accelerator "DESY" [4], was applied. Observation of the chamber information was realized using photocarders. It has been shown that the wide - gap spark chambers angular resolution is ≈2°. For photographic observation of gamma-quanta with the energy of 100 MeV it is ≈2°. For electrons with 2 GeV energy it is ≈0.8°. For SAS - 2 and COS - B the corresponding quantities for gamma - quanta with 100 MeV energy are ≥4° and 5% [1 and 2].

The use of photographic observations has many obvious advantages. During long experiments in space [≈1 year] many technical difficulties arise: either the necessity for a regulated photocassette recharging or large amounts (with respect to weight) of the phototape. The phototape returns to earth. In addition there is no possibility for fast data analysis. Entering this data into the computer together with the other telescopic parameters is inconvenient. Therefore, /4*
the gamma telescope and the photographic system for information observation are provided with the television [vidicom] system, which does not have the above-mentioned drawbacks.

However, the vidicon system is much more complex in its structure and requires transmission of large quantities of digital information from the satellite to the earth which is necessary to describe the

*Numbers in margin indicate foreign pagination.

spark "picture" in the spark chambers. In addition, there is no practical experience in using the television systems for information observation using wide-gap spark chambers either for airborne tests, or for tests on the earth. This article is devoted to the study of the vidicon system characteristics which were developed to operate with wide - gap spark chambers.

2. Vidicon System

The basis of the vidicon system is two television chambers used to obtain stereoscopic pictures of the spark chambers. Each vidicon chamber has a vidicon lens, tubes, video amplifier, amplitude discriminator, digital scanning block, power supply, and elcctronics for processing of the digital data of one event.

The vidicon system is started by the $M2_z$ and M_2 which are triggered by the telescope "Gamma - I" as soon as a gamma-quantum or charged particles are registered [3].

The development of the vidicon system was done with the following characteristics in mind:

Each of the 14 spark chambers gaps[length of the gap 30 mm] is beamed by three lines of the horizontal scanning with 17 mm distance between the end lines on the front wall of the chambers. The distance of 17 mm was chosen because the rear wall of the chambers pro-/5* jected on the front wall of the chamber has a height of 21 mm. [The distance from the vidicon to the front wall of the chamber is 1250 mm, the chamber depth is 500 mm], and the spark coordinates measurement is not to be done closer than 0.1 of the spark length, because closer to the electrode the spark does not follow the particle track. The middle line in the gap is on the level of the light marks at the end of each gap and has the same distance from the electrodes. Two end lines are located at equal distances from the middle line. By using remote control a change in the distance between the end lines - from 17 to 12.5 mm was predicted. Such a need may arise in the case of the slight change due to the vibration of the mirror inclination angles (pitch angles) bringing the picture of the spark chambers into the lens of the vidicom system. This could result in one of the lines being outside of the chamber's limit.

The coordinate scaling along the line is 4000,i.e., one degree is 0.125 mm on the scale of the front wall of the chamber [the dimensions of the spark chamber are 500 x 500 mm^2]. This coordinate step allowed us to obtain the spark inclination angle with a discretization of ≈ 0.4° for a distance of 17 mm between the end lines.

The angular discretization of 0.4° was chosen on the basis of the spark chamber calibration result with the accelerator DESY [4,5] which showed that the limit value of the angular resolution for the individual relativistic particles is ≈ 0,8°.

In order to limit the volume of the computed coordinate infor- /6* mation the length is determined only for the first eight sparks of the line and the whole number of the codes (digital bits) is not to be higher than 156 for each projection. In addition, in order not to overload the telemetry (remote control system) with "empty" information, certain events which satisfied certain requirements, were eliminated (not more than one spark in the gaps from 1 to 10 and absence of the sparks in the gaps 11 and 12). If the given conditions are satisfied in two projections [so called "white picture"] no data are transmitted from the vidicon memory.

Also, the data transmission will not occur if the master M in the first or second gap has one or a few sparks in X or Y projection.

The information about the taken picture is established as a result of the computation and analysis of the picture in the vidicon memory.

3. Data Structure

It is well known that the success or failure of any application of the digital computer (a vidicon system of the information observation is designed to operate only with the computer) strongly depends on an effective and convenient data structure which has been developed. Therefore, data structure development is very important.

The data flow contains the following information: number of sparks in each projection, number of the vidicon format, number of the gamma - telescope format which corresponds to the given format of the vidicon system, timer recordings (indications), the number of the turned-on gaps for each projection, video-signal discrimination threshold, number of codes (bits) per vidicon line, abscissa, and width of each videosignal.

The special feature of the developed structure is a high noise immunity. In each word [8 bits] one bit is a parity word control bit. Since the vidicom format length is variable, the key information words [gap number, number of the codes of the line] are protected by the use of the Hamming Code. This allowed not only a failure detection but a failure elimination too. In addition in order to avoid that some word might imitate the beginning of the format [sequence of 16 zeros] the words from 4 to 26 always have the seventh digit equal to 1. We have to remark that the given structure carrier of information between computers was a punched tape. During the processing some failures were corrected and the formats with the uncorrected failures were rejected. /7*

4. Measurement and Control Apparatus

For such a unique on-board space system as is the vidicon system, one needs complex measurement and control equipment. The tasks of such equipment are many,- far more than the task of a traditional system.

Control and measurement apparatus have to test the vidicon and the related electronics not only on the earth[during lab adjustment, during calibration with the cosmic mesons and gamma - quanta; during calibration with the accelerator] but also have to perform fast data analysis under space operating conditions of the gamma - telescope.

It is possible to formulate the basic function of the control -

measurement apparatus as follows:

1) Control of the apparatus function;
2) Experiment control for on-ground testing;
3) recording, storing and data processing. /8*

After careful analysis and selection it was decided to use the mini computer "Mitra 15/35" as the basic control.

"Mitra - 15/35" has a memory of 32K with 16-bit words; average instruction execution time 4 - 5 microseconds; it has also a highly developed interrupt system.

Peripheral equipment: serial printer LOGABEX LB 180 [180 word/sec] teletype ASR 33 with the writing and reading device for punched paper tape; alpha-numerical display, memory disc with a 5 M bits capacity with the fixed heads; input block for 32 analog signals, input block for digital information, output block for vidicon control, block for optical grid control.

In order to better use the possibilities of the computer, the programming "Assembler -2" Mitra 15" language was used.

The operating regime is a pseudo-dialog type. That means that the user at any level of the dialog may see a finite number of the orders (commands) listed on the display.

Using the commands generated by the display's button pressing, the user can change the videosignal discrimination threshold and the status of the triggered marks in each gap. He can turn different parts of the optical grid (for study purposes) on and off and give the triggering commands for u_y and M_z.

The data received from the vidicom system by the "Mitra-15" can be represented by the operator on the display screen, or by alpha numeric printer or on punched tape.

The punched tape is used for serial processing with high capacity computers.

1. instructions

The control of the analog signals [power supply current and voltage X, Y scanning current of the vidicon system projection] and structural data control are brought directly to the basic part/9* of the "Mitra-15".

5. Selection of the optimal vidicon system parameters

During the vidicon system development there were many unclear questions:

- What has to be the sensitivity of the vidicon with respect to the real spark?
- What has to be the allowed spark brightness range?
- What gives a better representation of the individual characteristics of the spark: coordinate of the video signal maximum and its amplitude or coordinate of the video signal front part at the given discrimination level and the width of the video signal at that level?

In order to answer these basic questions, a study model was developed consisting of four spark chambers, table model of the vidicon system and telescope having two scintillation counters located above and below the spark chambers. While the cosmic μ-ions were passing through, the telescope signal triggered the spark chambers and the vidicon system.

During the operation an oscillograph with memory was used as a recording device. The vidicon system has a line resolution (discretization) of 0.125 mm. The videosignal width and its amplitude dependence on different factors were investigated. Figure 1 shows two experimental dependencies: dependence of the average amplitude and the average videosignal width on the spark brightness. The same drawing shows the distribution [dispersion] of the measured quantities. The brightness was varied using different neutral filters in the optical path from the spark chambers to the vidicon lens. For the purpose of comparison, in the same figure are given the measurement results performed for the different power supply regimes of the spark chambers.

In the range of the brightness decrease 1 - 4 the amplitude of the videosignal reaches a saturation. For the multiple brightness /10* decrease for more than 15- 20 the amplitude dispersion [distribution] increases sharply, but the amplitude decreases. In the same time within the brightness decrease range from 4 to 15, the width and the dispersion (distribution) of the videosignal changes negligibly.

From the performed meausrements it follows that the optimal range for spark brightness variation is 4 - 15, and the videosignal amplitude is more variable within that range than the videosignal width.

The test data processing for the calibration measurement of the wide - gap spark chambers with the photographic information observation shows that the gap brightness is an important characteristic, useful for track identification. The dependence of the videosignal width on the gap brightness was investigated. The correlation coefficient 0.74 ± 0.04 shows that the videosignal width reflects the gap properties.

From the above-mentioned measurements two basic conclusions follow:

- The vidicon system can operate with the wide - gap spark chambers for a 4 - 15 fold brightness decrease:
- The videosignal width-the characteristic acceptable for the solution of the problems using wide - gap spark chambers.

6. Physical characteristics of the vidicon system

On the basis of the prestated requirements, experimental calibration results of the spark chambers using the accelerator DESY [4,5], and the experiment with the table model of the vidicon system was developed to be used with the wide - gap spark chamber gamma telescope "Gamma - I" for observation.

Tests were performed for the purpose of the detailed investigation of the vidicon system. The distinctive feature of the new

series of the tests is the quantity of the measurement performed /11*
for every test and the statistical approach that required full use
of the measurement control apparatus and its mathematical implementation.

6.1 Experiment with the vidicon system and optical grid on the optical bench

The optical grid and the vidicon system were located on the optical bench. Different optical grids were prepared. The optical grid is a plate with many slits at different places. Depending on the problem to be resolved optical grids with different slits were used, imitating straight and inclined tracks and tracks of different thicknesses. The optical grid was behind the flash lamp. Using a control table the experimentalist could control the light level of any point of the given optical grid. The flash lamp and the vidicon system were turned on with the signal "trigger". The data was fed into the "Mitra - 15" computer for processing. The brightness was varied with light filters.

Figure 2 shows the dependence of the videosignal width as a function of the optical grid slit length for different brightnesses. Figure 3 shows the dependence of the videosignal width as a function of the brightness for different lengths of the slits of the optical grid. The figures show that the vidicon for the range of the real spark length 1 - 5 mm has nonlinear characteristics. The preliminary estimate shows that the direction of the spark is determined as a straight line passing through three points. The coordinates of these three points are the coordinates and half of the videosignal width for the given discrimination level. The influence of the discovered nonlinearity of the "width" on the angular resolution will be discussed later.

6.2 Testing of the vidicon system with the wide-gap spark chambers

In order to perform the complex testing of the vidicon system, a set of 12 spark chambers were built. The vidicon system and a set of the mirrors which brought the picture of the spark chambers into the lenses of the vidicon system and photoapparatus were set up./12*

The case of the cosmic beam μ-ions passing through the spark chambers was fixed by the telescope having two scintillation counters located above and below the spark chamber tables. The signal from the telescope triggered the spark chambers and the vidicon system. The data was fed into the computer and onto punched tape for further processing.

The measurements were performed for the different distances between the lines [8.5 and 6.25 mm.] and with different discrimination thresholds of the videosignal. Data processing was done simultaneously and independently in the USSR and France.

For analysis, recorded cases were selected in each chamber for one spark. The recorded particle cases with less than three chambers and the cases with the dispersion (deviation) of the average direction more than 3° were not considered.

For each test we found:

- length distribution for each line of the vidicon system and for each gap;
- deviation distribution of the registered spark direction in the gap from the average direction
- error distribution for the spark direction in the gap from the average direction;
- distribution of the mean square deviation of the differences between the track inclination angles for two adjacent gaps.

Figure 4 shows the dependence of the videosignal average width as a function of the gap numbers for different videosignal discrimination thresholds. (For comparison in Figure 4 the videosignal width from the optical grids with the slit length 1 mm and a filter of multiplicity I). /13*

The vidicon system correctly transfers the expected width behavior as a function of the discrimination level of the videosignal. In addition, comparing the behavior of the spark length in the different gaps shows us the quality of spark chamber operation.

As we already said, the angular resolution of the spark chambers is decisive for the "Gamma - I" experiment. The angle half interval that contains 68% of the event was accepted as the angular resolution. The same criterion was applied for processing of calibrated measurement of the wide-gap spark chambers with the DESY [4.5] accelerator.

The dependence of the angular resolution on the particles incidence angle was investigated. The results are shown in Table I.

Table 1

Angular resolution dependence on the vidicon parameters and the particles incidence angles

NO.	Discrimination threshold of the videosignal relative to one	Distance between the lines in mm.	Angular resolution for different particle incidence angle in degrees.		
			≤ 7.5	≤ 15	> 7.5
1	1	8.5	0.75	0.95	1.05
2	4	8.5	0.75	0.95	1.05
3	7	8.5	0.75	0.95	-
4	4	6.25	.95	1.05	1.25

Table 2

The dependence of the angular resolution, as determined above, and other statistical characteristics obtained during the processing on the vidicon discretization step are shown in Table 2. /14*

	Discretization Step mm			
	0.5	0.25	0.125	0.125
mean square error	2.4 ± 0.9	2.2 ± 0.9	2.1 ± 0.9	3.7 ± 0.9
angular resolution	1.05	0.95	0.85	1.7
average error of the track direction determination	1.9 ± 1.4	1.7 ± 1.1	1.6 ± 0.8	2.9 ± 1.9

* The data were processed without taking into account the videosignal width.

In order to evaluate the influence of the optical distortion and other factors on the angular resolution in the spark chamber space the optical grid has the slits which imitate the straight tracks.

The fluctuation of the direction of these lines could be interpreted as the optical influence. The direction dispersion does not change with location in the chambers and has a value of $\simeq 0.12°$. The fluctuation after insertion of the glass [the thickness and type of the glass are the same as the lateral wall side of the spark chambers] is $\simeq 0.10°$. With the introduction of the English plastic YE 102 with a thickness of 1 cm, the fluctuation is $\simeq 0.27°$. The plastic acted as an anti-incidence protection of the gamma telescope "Gamma - I" [3].

The three types of fluctuations could be interpreted as a deterioration of the angular resolution:

$$\sqrt{0,12^2+0,10^2+0,27^2} \approx 0,31$$

7. Comparison of photographic and vidicon methods of information observation. /15*

The experimental set-up involves the photographic method of recording. At first it was important to compare the data of these two methods of information observation with respect to angular resolution and second to get results about the efficiency of the vidicon system.

Comparing the results, given in Table I, with the data of the calibrated measurement of the wide - gap spark chambers for the photographic observation [0.3°], it can be ascertained that the angular resolution of the wide - gap spark chambers in the case of the vidicon method of the information observation is not worse than in the case of the photographic method for individual particles.

The efficiency of the vidicon method is called the ratio of the recorded with the vidicon to the number of the sparks recorded with photorecorder. The efficiency can be found for each spark chamber separately and for all chambers immediately. The efficiency depends on the individual properties of each chamber, vidicon discrimination threshold and the type of event.

The events are classifed as two different types: single [S] and double [D] events. The single event corresponds to the one spark in the chamber and double events corresponds to more than one spark in the chamber. Table 3 shows the data for the efficiency estimation. As in the above described calibration experiment using α-ions, the statistical considerations for the double events were simple and the results were averaged over all twelve chambers.

To evaluate the efficiency of the vidicon recording for gamma quanta, changes were introduced. A converter was located above the spark chambers. The telescope having three scintillation counters selected the case of particle generation in the converter material. The average value of the efficiency of the vidicon system for the discrimination threshold 0 is 88$\pm$ 3%. /16*

Table 3 Dependence of the vidicon system registration efficiency on the type of event and the vidicon discrimination threshold.

Type of Event	Videosignal discrimination threshold		
	1	4	7
S(single)	100%	98$\pm$1%	-
D(double)	80$\pm$5%	72$\pm$ 4%	54%

8. Conclusions

As a result of the study performed together by the Soviet and French specialists - an experimental investigation was made of the vidicon system of information observation using wide - gap spark chambers.

These experiments showed that the basic characteristics of the vidicon system are not worse than the characteristics of the photographic system. The angular resolution of the spark chambers, achieved by the use of the cosmic ray muons is ≈0.8°.

Wide experience has been gained in operations with vidicon, and a method for vidicon information processing was developed.

The developed system of vidicon information observation using a wide-gap spark chamber, without question, could be used in the Soviet - French experiment "Gamma - I."

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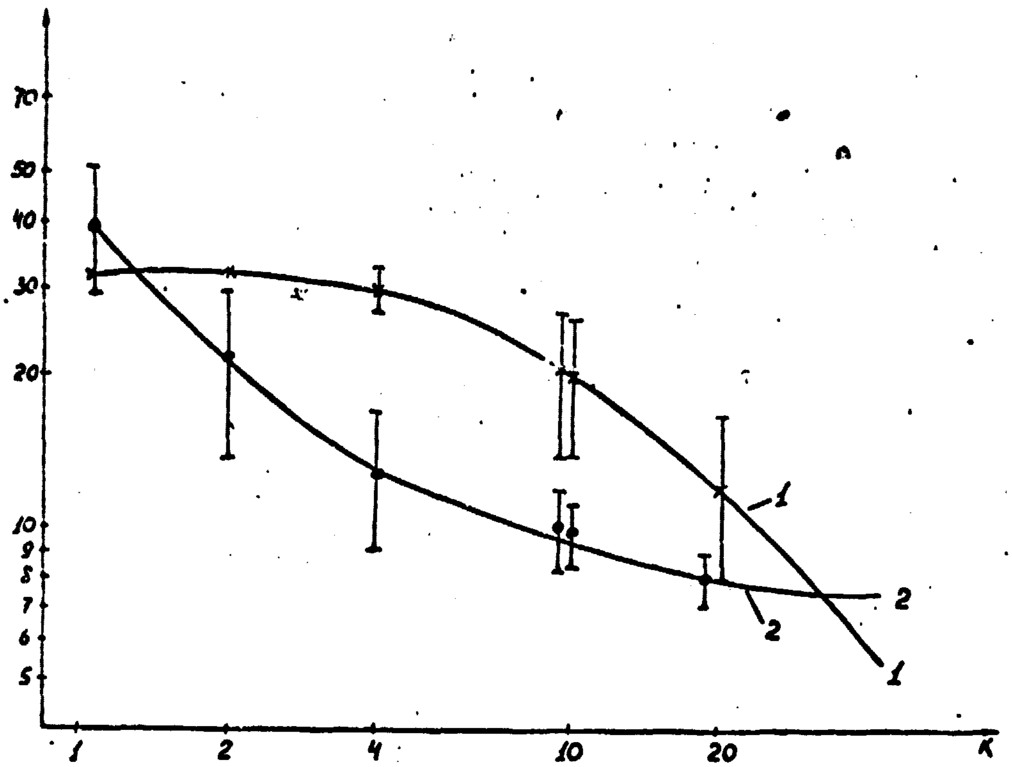

19*

Figure 1: Dependence of the average amplitude and average videosignal/18* width on the spark brightness. The ordinate axis represents the amplitude [1] and the width [2] of the videosignal in relative units. The abscissa axis represents the attenuation coefficient of the spark brightness.

/20*

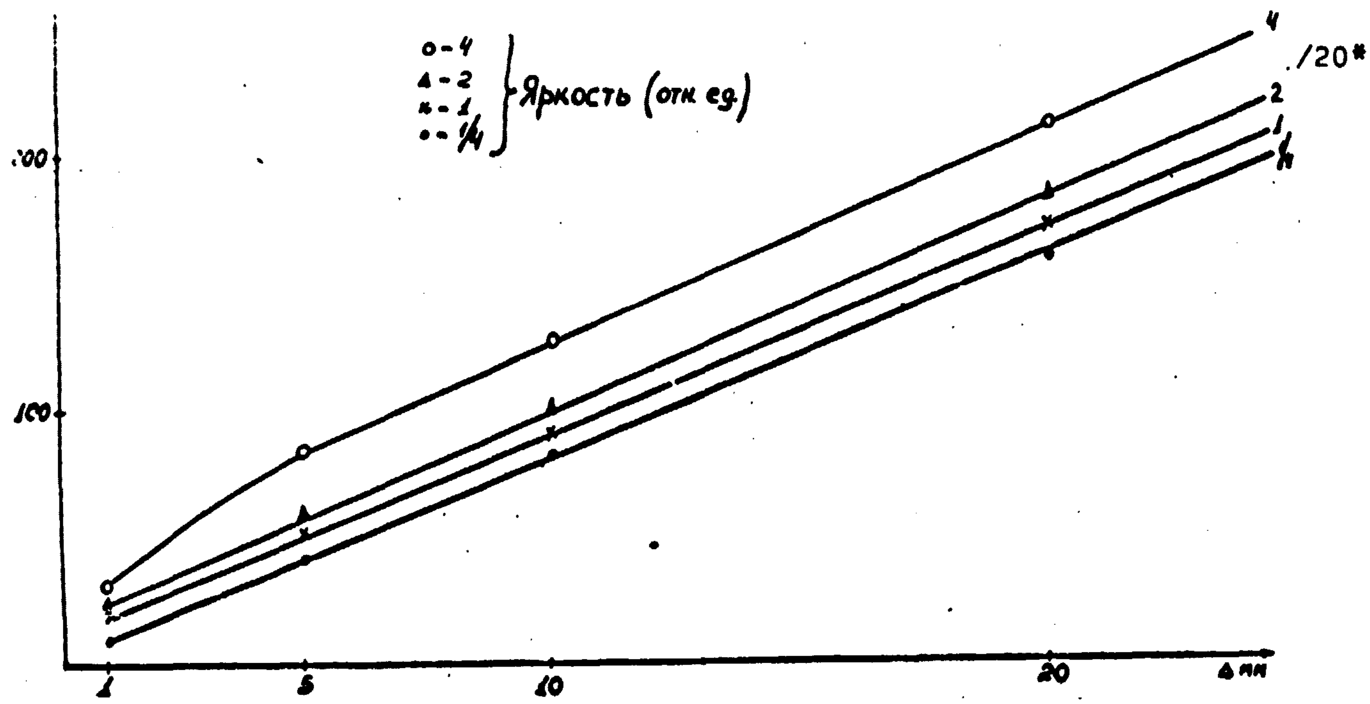

Figure 2: Dependence of the videosignal width, relative units, on the optical grid slit length.

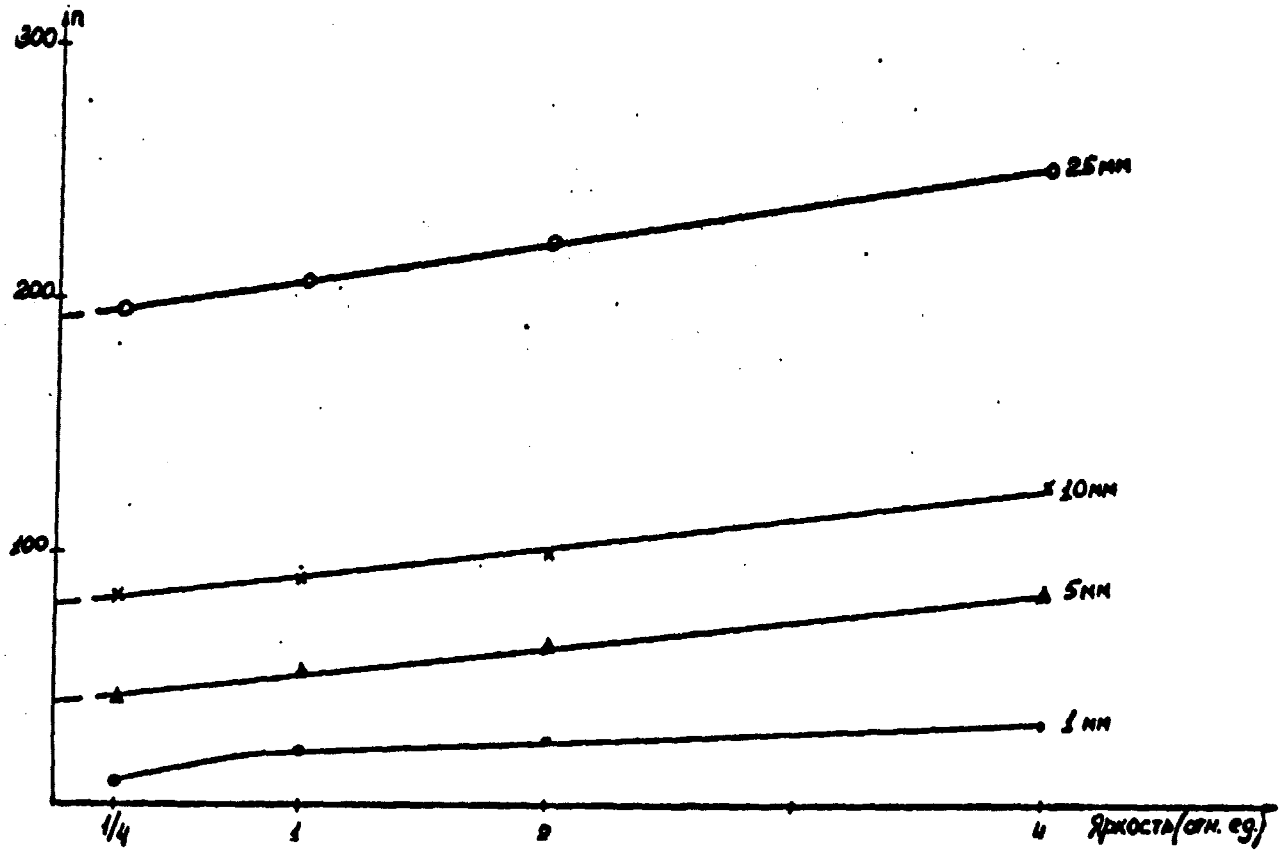

Figure 3: Dependence of the videosignal width, relative units, on the brightness for different slit lengths of the optical grid.

/22*

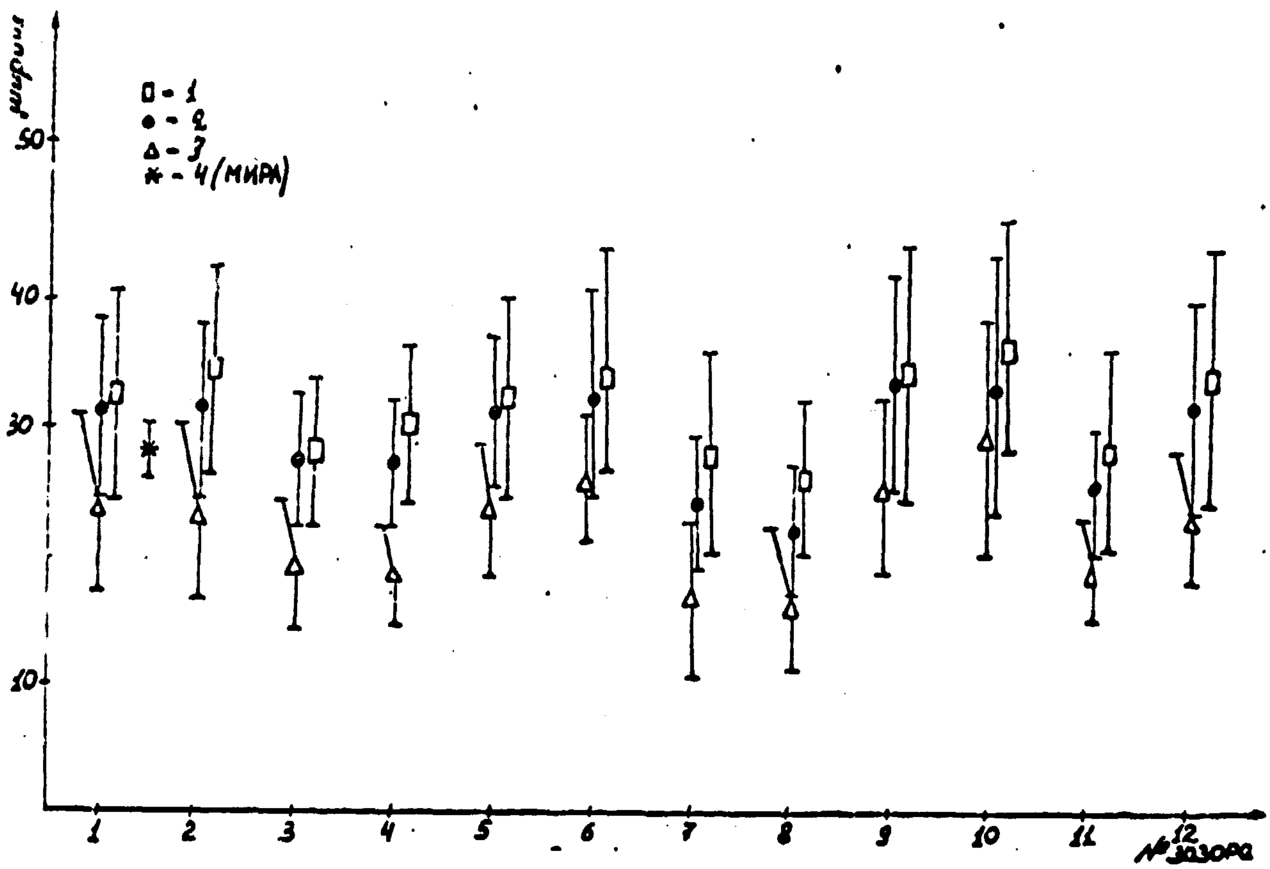

Figure 4: Dependence of the average width of the videosignal on the number of the gaps for different videosignal discrimination threshold. On the ordinate axis - the videosignal width in the same scale as vidicon scale [0.125mm], on the abscissa axis - gap number. The correspondence between the points on the graph and the videosignal discrimination threshold is the following: I - threshold I; 2 - threshold 4; 3 - threshold 7; 4 - the videosignal width from the optical grid with the slit length of I mm and threshold 4.